Reviewer's Report for the Center of Independent Experts (University of Miami)

Pacific Sea Turtle Assessment
Meeting site: Honolulu, Hawaii
Date: 2 to 3 May 2002

Reviewer: Stephen J. Smith
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Executive Summary

All of the models reviewed appeared to use the available information on the turtle species in a reasonable way, albeit there were differences in model structure. The eastern Pacific leatherback model behaved in a counter-intuitive manner when assessing the impact of reducing all human induced mortality. This behavior could be avoided by changing the tuning methods for determining equilibrium conditions. The two most important differences between the models for the eastern and western Pacific populations of leatherback turtles were the omission of temperature effects in the former model and the different ways of incorporating density dependent effects in both models. Beach temperature was identified as an important factor in hatchling survival and determining the sex ratio of the hatchlings for the western Pacific population and relationships pertaining to these were included in the model for this population. While the importance of temperature was also acknowledged for the eastern Pacific population, no relationships with temperature were included in the model for this population. The density dependent mechanism built into the models will directly affect how the populations are predicted to recover for candidate mitigation measures. The two leatherback models differed in how density dependence was structured and further work on determining the best way(s) of incorporating these effects was recommended. Recommendations were made on developing a tool kit for evaluating the performance of these models. Considerations on how the information obtained from these models would be expressed and summarized when used in public fora were also discussed.

Background

Simulation models have been developed to provide means of assessing the impact of human activities on populations of Pacific leatherback turtles in the eastern and western Pacific Ocean, and loggerhead turtles in the Northwest Pacific Ocean. There is very little monitoring data available on any of these populations, and therefore traditional stock assessment models that predict population numbers or biomass based on such data are not available. The approach taken in the work reviewed here was to construct dynamic state-space models that incorporated demographic information that was either known or could be assumed for these turtles. These models provide mathematical systems that operate in a manner that reflected the researchers' best judgment of how turtle populations should behave. The impact of human activities, such as harvesting eggs or cessation of fishing, was evaluated by introducing these activities into the model populations. There are a few limited time series of counts of mature females on nesting grounds, but these are not extensive enough to validate the model results, nor do they offer any information on the other life stages of the turtles, most of which are rarely observed by humans.

Review Activities

The Center for Independent Experts (CIE) supplied me with three documents and two computer code files on the 19th of April 2002, via email. The first document described the model developed by Dr. Jerry Wetherall (NMFS) and associates for the Mexican or eastern Pacific leatherback turtles (Wetherall et al. 2002). The remaining two documents described the model for the western Pacific leatherback population (Chaloupka 2002a) along with a user's guide for the computer models (Chaloupka 2002b). The document describing the model for the northwestern Pacific loggerhead sea turtle population (Chaloupka 2002c) did not arrive by email until the 29th of April. These later three reports were prepared by Dr. M. Chaloupka, a consultant based at the University of Queensland in Australia. URL links to the 2001 Biological Opinion on the western Pacific pelagic fishery and the 2001 final environmental impact statement (EIS) on the western Pacific pelagic fishery were also supplied to me for background information. The statement of work had indicated that materials from the green sea turtle workshop would also be supplied, but these materials were not sent out and, in the end, were not considered for the review.

The two computer files contained code for running the models described in the three documents by Chaloupka using a public domain runtime version of the Madonna computer package. I installed the Madonna runtime package on my computer. Unfortunately, the computer code files sent by the Center appeared to be corrupted and were not recognized by the Madonna package. New files were sent on the 29th of April that were recognized by the Madonna package, but errors were encountered when the models were manipulated in the screen configuration presented in Chaloupka (2002c). I notified the Center of my problems and received a solution via email from Drs. Wetherall and Chaloupka late on the 30th of April. By this time, it was too late to do very much with the software, as I had to spend the whole of May 1st traveling to Honolulu. No computer code was supplied for the model of the eastern Pacific leatherback turtle populations.

In Honolulu, the other reviewer, Graham Pilling and I met with Jerry Wetherall, Milani Chaloupka and the director of the Honolulu Laboratory, Michael Laurs, on the morning of May 2nd. Jerry Wetherall presented his model to us throughout the morning, fielding questions from Graham and me, based on our analyses of the documentation in Wetherall et al. (2002). We discussed the western Pacific leatherback with Milani Chaloupka in the afternoon and returned to discuss the northwestern loggerhead on the morning of May 3rd. In the afternoon of May 3rd, we had a general discussion of how these models could be used in interactions with different interest groups to discuss impacts of human activities on the turtles.

The sessions on May 2nd and 3rd were very informal and meant to be an onsite peer review of models being used. I got the sense from the director and the other participants that they were unsure of the purpose of this kind of review. Dr. Laurs indicated that he was unaware of the history of and the motivation for the Center of Independent Experts. Perhaps the Center and/or NMFS headquarters could invest in some outreach activities with the NMFS laboratories to clear up possible misgivings that could be still out there. Has a summary or evaluation of the Center's activities to date been written and distributed to the regional laboratories?

I returned home on May 4th and continued to analyze the documents and try different scenarios with the computer code.

Summary of findings

Leatherback turtles

There is limited information on growth, mortality, remigration rates, etc., for leatherback turtles in the literature. After comparing how the different models made use of this limited information, I believe that both leatherback models made the best use possible. There were of course differences in implementation, with Chaloupka's model using probability density functions to translate literature-based or best guesses of demographic parameter values into stochastic ranges of likely values. Wetherall et al. (2002) only presented a deterministic application of their model. Although a stochastic version was supposed to be available, we did not receive any information on how the stochastic features were implemented.

I found two major differences between the model structures used for the leatherback turtle populations. The first concerned the incorporation of beach temperature effects into the hatchling survival and sex ratios in Chaloupka's model. Wetherall et al. (2002) acknowledged that temperature was important but did not incorporate it into the model, nor did they have sex ratio in their model. A trend of increasing beach temperatures in the nesting grounds in Malaysia due to development and clearing of vegetation was concluded to be important for the western Pacific population of leatherback turtles. If there is a similar concern for the eastern Pacific population, then beach temperature should be included in any model of this population as well.

The second difference concerned the incorporation of density dependent effects into the two leatherback turtle models. Both Wetherall and Chaloupka pointed out that based on their experience from modeling populations, populations cannot recover from extensive exploitation without some form of density dependence, where the highest growth and fecundity levels are assumed to be associated with the lower population levels. Therefore, it is important to consider how density dependence is structured in the models if we are going to use them to evaluate the impacts of human activities.

Eastern Pacific Leatherback turtles

For all of the evaluations conducted in the report on the eastern Pacific leatherbacks, the turtle population was structured with either linear or non-linear density dependence, and low, medium or high natural survivorship. Density dependence was modeled to affect three aspects of the model — hatchling production, variation in growth and remigration.

Hatchling production is directly related to the adult population size through the density of egg clutches (via a Ricker recruitment curve) and the related probability of nest superimposition. As the population increases, the Ricker curve and the increasing probability of nest superimposition results in decreasing hatchling production.

Density dependence for growth was linked to food supply through modeling growth rate (K parameter) as a function of food per capita, assuming a constant food supply over all cases. However, Beverton and Holt (1957) suggest that in the von Bertalanffy model, the parameter for maximum size (l_{max} in equation 15) is proportional to the cube of the ratio of the coefficients of anabolism and catabolism, while K is proportional only to catabolism. Changes in food supply would solely affect the rate of anabolism and such a change would then only be reflected by changes in l_{max}. Changing the turtle model to confirm to this viewpoint would change the dynamics of the growth model and the probability of a turtle of length l growing to length $l+k$ in the time interval. In the current model of Wetherall et al. (2002), the growth rate would approach K_{min} as the food supply decreases (as population approaches P_0) while the above change would keep the growth rate the same and the maximum size would decrease. Apparently, turtles can stop feeding for a long period of time and survive in an emaciated state. If this cessation of feeding is a response to density dependence, then which approach to use to model changes in growth depends on whether the potential maximum size decreases or if the animals can rebound when food becomes more abundant and continue growing to the same maximum size.

The rate of reproductive recovery (number of years between breeding events for a particular female) or remigration propensity was also linked to the food supply per capita. Casting density dependence as linear or non-linear with population size was only incorporated in the relationships for growth and reproductive recovery.

The natural survivorship levels referred to those set for juveniles, sub-adults and adults. Neonate survival was computed or tuned to these other levels during the initialization of the simulation model. Survivorship rates used for the model are presented in Table 1 of the document. Increasing adult survival from 0.80 to 0.95 resulted in the decline of neonate survival from 0.27 to 0.02.

The evaluation of mortality reduction scenarios in section 9 of Wetherall et al. (2002) points out some behaviors associated with these relationships and assumptions that may not be desirable for this kind of model. The three management scenarios of status quo, maximum mortality reduction and partial mortality reduction were explored.   At the top of page 23 (my copy of Wetherall et al. (2002)) the authors state that the maximum mortality reduction scenario, i.e., all human-caused mortality eliminated beginning in 2001, resulted in recovery within the 100 years threshold for the case of low natural survival whether density dependence was linearly or non-linearly related to population size. However, for the cases of moderate or high survivorship, the maximum mortality reduction scenario did not result in recovery within 100 years and "… in most cases the simulated populations simply continued to decline."

The fact that populations with high survival rates would not benefit from the elimination of anthropomorphic mortality appears to be counter-intuitive. How did these populations survive before humans began to exploit them? Generally, populations with high survivorship may have lower growth rates and fecundity than those with lower survivorship. In this way, the former type of population may not recover as fast as the latter type. However, Jerry Wetherall confirmed during our meeting in Honolulu that the same growth rate and fecundity was used for all levels of survivorship. Therefore, the results appear to be solely a function of the tuning process that set high juvenile, sub-adult and adult survivorship at the expense of that for the neonates. Combine the low neonate survivorship with density dependence and it is no wonder that the populations did not recover.   How realistic is the structure used here that establishes equilibrium conditions requiring high mortality rates for the neonates? The neonates and the older life history stages of the turtles do not appear to occur in the same place and therefore do not interact or compete for the same resources. The authors note that the low recovery rates predicted for the moderate and high survivorship cases were in contrast to available observations on leatherback populations.

Western Pacific Leatherback turtles

Unlike Wetherall's model, Chaloupka's model tuned the survival probabilities for the juvenile age groups using set ranges of survival probabilities for all of the other age groups. The survival probabilities for neonates ranged from 0.1 to 0.22 with the other probabilities similar to those used in the eastern Pacific model. As a result, Chaloupka's model is unlikely to exhibit the same counter-intuitive behavior that Wetherall's model did when evaluating mitigation measures for different ranges of survival probabilities.

Chaloupka (2002a) relates density dependence to food availability and acknowledges that food availability could have an effect on growth and breeding behavior. However, his model only considered breeding behavior by assuming that sex and substock-specific breeding probability functions were density dependent. That is, as the population increased, the probability that females would breed decreases. Depensatory density dependence effects were also part of this model, with the probability of a female finding at least one male to mate with also being related to population density.

While there are slider controls for setting the age and size at maturity, growth is not connected to density dependent processes. I see this omission of a relationship between growth and density as being a problem for this model and believe that attention should be directed to including some such relationship into the model. We were told that it is likely that Chaloupka's model will be adopted for the eastern Pacific leatherback turtle population. If that is the case, the merit of including a relationship between density and growth should be evaluated as well as the relationship with nest superimposition from Wetherall's model.

Loggerhead turtles

There is even less stock specific information available for the northwest Pacific loggerheads than there was for the leatherback populations. Much of the discussion about this model was similar to that for the western Pacific leatherback model. I am not a sea turtle expert and could not evaluate if the model structure reliably reflected the general life history of the loggerhead turtles. However, one concern that I did have for this model (and for the leatherback model) was the possibility of multiple equilibrium points. That is, the sensitivity analysis in Figure 15 of Chaloupka (2002c) identified the combination of levels for a subset of parameters that resulted in equilibrium conditions (stock growth rate balanced by mortality). The trends of the parameters were linear with respect to the growth rate for the limited ranges considered in this analysis. However, this is no guarantee that for a wider range of levels, the trend would not be quadratic and therefore could cross the equilibrium line at two points resulting in a number of different combinations of parameter levels that could give equilibrium conditions. The impact of multiple equilibria would be that the starting conditions for the model would not be unique. Parameter sensitivity analysis could pick this problem up as long as this diagnostic tool was used for all future combinations of parameter settings. In the application presented in Chaloupka (2002c), only a subset of parameters was considered because of the large numbers of computations that needed to be done. Attention should be directed to constructing tools that could more efficiently detect problems such as multiple equilibrium points in all of the parameters in the model.

General considerations

For models where there is monitoring data, diagnostics based on goodness-of-fit and complexity from statistical theory can be used to assess model performance. For the models used in the reports reviewed here where there are little monitoring data, there are at present few methods for evaluating model performance. The application of multi-factor parameter sensitivity analysis and autoregressive spectral analysis for the Madonna based models appear to be useful ways of assessing performance in the absence of data.

Clearly, there is a need for more general or case-specific tools to aid researchers in assessing these kinds of models.

Both Wetherall and Chaloupka acknowledged that the Madonna based models were more versatile, faster and more interactive with a convenient user interface. This interactivity could be a double-edged sword. On the one hand, the user interface allows for easy implementation of a large number of potential scenarios for a given model structure. However, for each scenario a large number of results are displayed on the computer/projector screen and after a number of scenarios one can easily lose their perspective on what does and doesn't work.

Conclusions/recommendations

The models reviewed here represent useful approaches for summarizing the available demographic information for the leatherback and loggerhead turtle populations. However, their usefulness for evaluating actual mitigation measures will be highly dependent upon the model structures and the quality of the data being used. Given, that for leatherback and loggerhead turtles it could take up to 15 years and 25 years, respectively, to observe the actual results of these measures, the structure of the models and reliability of the data is crucial. I do not believe that the analyses reviewed here represent the best available information on which to proceed with protected species recovery and fisheries management due to problems with the model structure and data quality.

I have two major concerns about structural problems with the models. The model for the eastern Pacific behaved in a counter-intuitive manner when assessing the impact of elimination of human induced mortality on populations with high survival rates. This behavior could be avoided by obtaining accurate survival rates for neonates and tuning to equilibrium by adjusting growth or fecundity or some combination of these.

However, mitigation measures will be evaluated in terms of how quickly the models predict that the populations will recover from severe perturbations. This ability to recover is in turn a function of the degree of density dependence built into the models. Both Wetherall and Chaloupka note that density-dependence is not well understood for sea turtles and further, risk assessment can be quite sensitive to the functional form assumed for density-dependence. The two leatherback models have their own versions of density dependence and therefore would possibly predict different recovery rates for similar parameter values. If the model approach used in Chaloupka (2002a) is going to be adopted for the eastern Pacific area, then the density dependence relationships in this approach need to be reconciled with those used in Wetherall's model.

Wetherall (2002) identified maximum growth rate and maximum remigration propensity as key parameters for his leatherback model, while Chaloupka (2002a) found that his model was most sensitive to the quality of annual breeding probabilities and age-class-specific maturities. The first three quantities were explicitly included as density dependent functions while age-class-specific maturities could very well be related to density. All of these quantities were classified as being poorly estimated. Therefore, not only are there questions about the form of density dependence that can be assumed but also key quantities for these relationships are poorly known.

I recommend that the above problems with the models be addressed before NMFS proceeds to use them to develop species recovery plans. NMFS should initiate a project on evaluating potential density relationships for these turtle populations to be used in the future applications of these models as well looking at mitigation measures that are robust to the degree of density-dependence assumed for the models. Data necessary to estimate quantities such as annual breeding probabilities and age-class-specific maturities also need to be collected.

The model developed for the northwest Pacific loggerhead turtles seems to be reasonable given the state of knowledge about this particular population. However, all of the demographic data used for this population was derived from the more studied southern Pacific population. We really need a better sense of the potential differences between these two populations with respect to the parameters being estimated before this model can be used to develop recovery plans. Chaloupka (2002c) identified the proportion of females breeding, the maximum number of clutches in each season, and the pelagic and benthic age-class survival rates as being key parameters in the model and NMFS needs to focus their attention on obtaining data on these for the northwest Pacific population. Comments above on defining the density dependent mechanisms apply to this model as well.

Attention should be directed to developing general or case-specific tools to aid researchers in running and validating these models. Models tend to get used in ways that the developers did not intend or expect. It is possible that given a wider range of survival rates, the models may actually identify multiple equilibrium and diagnostic tools should be available to identify if this occurs. A gold standard version of the model software needs to be kept secure as a benchmark for any future revisions or alterations of the model.

The interface provided with the Madonna programs is very convenient for working with a group of people to ascertain potential impacts or benefits from human activities. However, as noted above, the ease of trying different combinations of settings for the model could easily fatigue the group, and the message may become lost or confused. NMFS should consider ways of summarizing the results of each run of the model in a hard copy that participants can take away with them at the end of the meeting. I do not mean copies of screen dumps of the various graphs etc.; instead, I am thinking of a more focused presentation that targets the purpose of the public consultation (closed areas, reduced egg harvesting, etc.) and distills the results down to a small number of displays.

References

Beverton, R.J.H., and S.J. Holt. 1957. On the dynamics of exploited fish populations. U.K. Min. Agric. Fish., Fish. Invest. Series. 19: 533 pp.

Chaloupka, M. 2002a. Development of a stochastic metapopulation model for the western Pacific leatherback sea turtle stock. Report prepared for the US National Marine Fisheries Service, Southwest Fisheries Science Centre, Honolulu Laboratory, Honolulu, Hawaii.109 pp.

Chaloupka, M. 2002b. Stochastic simulation model of Western Pacific leatherback sea turtle metapopulation dynamics. User's guide. Report prepared for the US National Marine Fisheries Service, Southwest Fisheries Science Centre, Honolulu Laboratory, Honolulu, Hawaii. 41 pp.

Chaloupka, M. 2002c. Development of a stochastic population model for the northwestern Pacific loggerhead sea turtle stock. Report prepared for the US National Marine Fisheries Service, Southwest Fisheries Science Centre, Honolulu Laboratory, Honolulu, Hawaii.102 pp.

Wetherall, J., L. Sarti, P. Dutton and D. Garcia. 2002. Status of Mexican leatherbacks in the Pacific Ocean: A simulation of human impacts. Unpublished manuscript dated April 15, 2002. 62 pp.

APPENDIX I: BACKGOUND DOCUMENTS

Chaloupka, M. (2002). Development of a stochastic metapopulation model for the western Pacific leatherback sea turtle stock. Report prepared for the US National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, Honolulu, Hawaii. 109p.

Chaloupka, M. (2002). Stochastic simulation model of western Pacific leatherback sea turtle metapopulation dynamics – User's Guide. For the US National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, Honolulu, Hawaii. 41p.

Chaloupka, M. (2002). Development of a stochastic population model for the western Pacific loggerhead sea turtle stock. Report prepared for the US National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, Honolulu, Hawaii. 102p.

Chaloupka, M. (2002). Stochastic simulation model of northwestern Pacific loggerhead sea turtle population dynamics – User's Guide. For the US National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, Honolulu, Hawaii. 37p.

Chaloupka, M. (2002). Stochastic simulation modeling of southern Great Barrier Reef green turtle population dynamics. *Ecological modeling* 148, 79-109.

Chaloupka, M. and Limpus, C. (2001). Trends in the abundance of sea turtles resident in southern Great Barrier Reef waters. *Biological conservation* 102, 235-249.

Chaloupka, M. and Limpus, C. (2002). Survival probability estimates for the endangered loggerhead sea turtle resident in southern Great Barrier Reef waters. *Marine Biology* 140, 267-277.

National Marine Fisheries Service, 2001 Biological Opinion on the western Pacific pelagic fishery. URL: http://swr.nmfs.noaa.gov/piao/wpfbofinal/wpfbo.htm

National Marine Fisheries Service, 2001 final Environmental Impact Statement (EIS) on the western Pacific pelagic fishery. URL: http://swr.ucsd.edu/piao/eisdocs.htm

Wetherall, J., Sarti, L., Dutton, P. and Garcia, D. (2002). Status of Mexican leatherbacks in the Pacific Ocean: A simulation of human impacts. Draft manuscript, 62p.

APPENDIX II: STATEMENT OF WORK

Consulting Agreement Between The University of Miami and Dr. Stephen Smith

General

Simulation models have been developed to provide a quantitative foundation for assessing impacts of the Hawaii-based pelagic longline fishery and other human activities on sea turtle populations. Two independent studies have just been completed. One study involved the development and application of a stochastic simulation model of Pacific leatherback sea turtles, with emphasis on western Pacific populations of this species, and a second simulation model of Pacific loggerheads. These models were developed under contract by a sea turtle modeling specialist assisted by interactive workshops of invited experts. The other study involved the development and application of a simulation model of the Mexican leatherback population in the Pacific by a NMFS modeler in collaboration with two Mexican leatherback experts, using a different modeling approach. These analyses, which evaluate the dynamics of sea turtle populations and their sensitivity to longline fishing and other human-caused mortality factors, need to be reviewed independently. The reviews should examine the assessment methods, models, and findings.

These reports are expected to play an important role in the development of mitigation and recovery efforts by the NMFS Southwest Region through fishery management regulations and other measures, likely in the context of an ESA biological opinion on the Hawaii longline fishery. As a result, the review should consider not only the basic population science underlying these models, but also the applicability of the models to evaluation of mitigating effects and the analyses' use of the best available information on both population modeling and sea turtle biology.

The reviewer shall analyze the reports for loggerhead and leatherback sea turtles, focusing on the following:

1. Assumptions in defining the stock structures based on genetic or other information;
2. Application of the most recent biological, nesting beach, and fishery interactions data;
3. Underlying dynamics of the population models;
4. Applicability of the population models to the ongoing protected species recovery and fisheries management issues.

Specific

The reviewers duties shall not exceed two weeks – several days to review the reports (two of which are parallel in structure and simulation methodology); participation in a two-day workshop in Honolulu, Hawaii, on May 2-3, 2002, which will focus on the use of the first (stochastic simulator's) approach for developing a model of the Hawaiian green sea turtle population; and several days to produce a written report of the findings. Finally, no consensus, pre-final review, or rejoinder comments are required.

The itemized tasks of the review include:

1. Analyzing the following documents provided to the consultant by the NMFS Honolulu Laboratory:

    a. Leatherback turtle stock assessment simulation report by Dr. Milani Chaloupka, including narrative description, workbooks, and model code;
    b. Loggerhead turtle stock assessment simulation report by Dr. Milani Chaloupka, including narrative description, workbooks, and model code;
    c. Mexican leatherback simulation model report by Dr. Jerry Wetherall, Laura Sarti, and Dr. Peter Dutton.

2. Reading (no commentary required) the following background documentation provided to the reviewer by the NMFS Honolulu Laboratory:

    a. 2001 Biological Opinion on the western Pacific pelagic fishery;
    b. 2001 final Environmental Impact Statement (EIS) on the western Pacific pelagic fishery; and,
    c. Materials for the green sea turtle workshop provided by the consultant.

3. No later than May 20, 2002 submitting a written report of findings, analyses, and conclusions concerning the three sea turtle stock assessment simulation reports. This report must address the utility of the population simulation models and methodology to answer questions concerning the status of Pacific leatherback and loggerhead sea turtle populations and the assessment, mitigation and reduction of human-caused mortality. The report must include the following elements:

    a. Executive summary of findings and recommendations.
    b. Main body consisting of background; description of review activities; findings and conclusions; and recommendations. The conclusion must contain a statement as to whether the analyses represent the best available information on which to proceed with protected species recovery and fisheries management, and whether the information quality is sufficient for basing development of management strategies.

The report should include as separate appendices the bibliography of all materials referenced in the review, including those documents provided by the Center for

Independent Experts and the Southwest Fisheries Science Center; and a copy of the statement of work.

Full photocopies (or PDF files) and citations of all papers, reports or other written materials cited by the review should be provided separately.

The final report[1] should be addressed to the "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via email to ddie@rsmas.miami.edu.

Reviewer name: ________________________

Signature: ________________________ Date: ________________

[1] The written report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of the written report that will be submitted to NMFS and the consultant.